Soumis le : 26/04/2014
Forme révisée acceptée le : 17/01/2017
Auteur correspondant: sidahmedathmane@yahoo.fr

Nature & Technology

Prediction the life of the composite material to a fatigue test

Athmane Sid ahmed , Abdelkrim Aid, Abdelghani Baltach, Mohamed Chaib and ali Zine el abidine Arab

LPQ3M Laboratory, Department of Mechanical Engineering, university mascara29000, Algeria.

Abstract

The goal of this work is to assessing the life of the composite material. This research is subdivided in two parts: The first part is to compare the results found using numerical simulation with those obtained experimentally by alternating traction tests. In this study we used the ANSYS to validate the experimental results and evaluate the life of the unidirectional composite glass / epoxy under constant amplitude loading. The numerical results of these tests were also able to trace the curve of Wöhler using the criterion of life which corresponds to a total rupture of the specimen. This curve shows a dispersion of life in the case of trials. The second part presents the numerical results of life simulation of this material under block loading variable amplitude in three stress level cases.

Key words: Composite material, numerical simulation, the life, ruptures

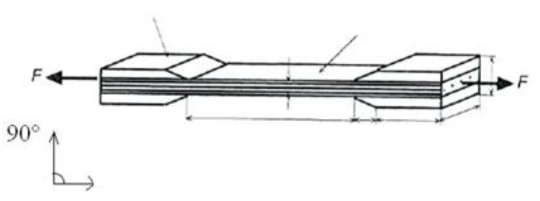
1. Introduction

Parts manufactured in composite are increasingly used for longer periods and under conditions more difficult. But the life of composite structures is still poorly understood. To overcome these problems, often large safety factors are used in the design to ensure the safety of the parts. This is why the fatigue strength of the composite becomes a major industrial problem. The fatigue phenomenon of a material is characterized by its strength after application of a large number of cyclic loadings whose amplitude is less than the resistance to the static out of tiredness material. The leaves characteristic marks on the fracture surface (streaks) [1]. This phenomenon is frequently encountered in many industrial fields which involve cyclic loading, vibration loads, etc. The first fundamental studies of the fatigue phenomenon have been undertaken by Wohler on metals. At present, these are materials for which the most extensive on this subject is available knowledge. On other complex materials such as composite materials, particularly composites widely, the fatigue phenomenon is little mastered this limits their use. Fatigue even at a much lower loading to the fracture strength in static, a progressive drop of the characteristics due to the damage is observée.la degradation properties may depend in part on the initial defects (inclusion bubbles air) and the misalignment of the fibers during the manufacture of [2] composites.

During recent years, the work in the literature showed that the fatigue phenomenon depends on several parameters (type of biasing, loading, frequency of loading, etc.). This discussion is intended to evaluate the life in fatigue of a composite material. This work is considered a simulation comparison study by the method of finite elements and work already done in the laboratory [3], on the analysis of damage to composite materials.

2. Specimen geometry

The geometry of the tensile specimen (NF EN, ISO 527-5 is shows in the figure below (figure 1)



L_1= 150 mm L_2= 10 mm L_3= 40 mm
W= 15 mm t = 2.2 mm T= 6 mm

Figure 1: La géométrie de l'éprouvette [3]

3. Properties of the material used in the study

The material properties used in this study (composite glass / epoxy) are shown in Table 1

Table 1
Mechanical properties of a UD glass / epoxy fiber direction [3]

	Tensile limit (MPA)	Tensile Modulus (MPA)	Poisson coefficient	Flexion limit (MPA)	Flexural modulus (MPA)
Properties	1 300	42 000	0.25	1 200	41 000

Table 2:
Intrinsic properties of a UD glass / epoxy [3].

Structure	The element	Density (g/cm3)	Fiber volume (%)	Thickness of a ply (mm)
Unidirectional	fiber	2,6	55	0,75
	resin	1,6		

4. Presentation of the calculation software

The design and calculation software computer assisted are many on the market. The most used are Nastran, Catia, ANSYS, ABAQUS and SolidWorks. All these software perform the same tasks, ie they generate structures, its characteristics and those of the problem studied, then they calculate fate of this structure (deformations, breaks, plastic ...) and finally they can process these results in order to get out of usable and actionable data. Most companies use a mix of these programs that are more or less powerful in one or other of these tasks, for example, draw with Catia, ANSYS or ABAQUS calculate and do post-processing with Nastran. The study aims at the development of reliable predictive models for the numerical simulation behavior structures.ces numerical models allow completing the results obtained experimentally. Various behavior models of the various materials has been found in the literature [4-11].

5. Mesh

ANSYS workbench software has a powerful automatic mesh, which can analyze the geometry and generate the most appropriate mesh for the studied behavior (the mesh of the specimen is shown in Figure (2), it contains 2544 nodes and 1041 elements.

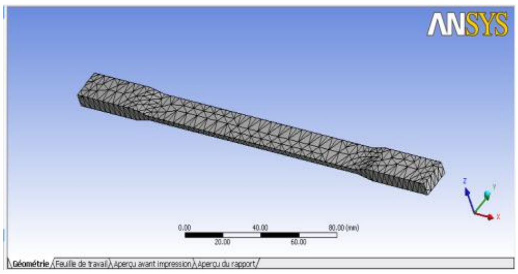


Figure 2: Mesh of the specimen by ANSYS.

6. Applied loads and boundary conditions

For the boundary conditions, we fixed a side of the specimen by the fixed support control is regarded as a recess. (Figure 3.A).and for loading; a load is applied on the other side of the specimen with an initial value of 0.3 N due to the fixation of the specimen in fatigue machine by the two jaws using the force-charge command (figure 3.B).

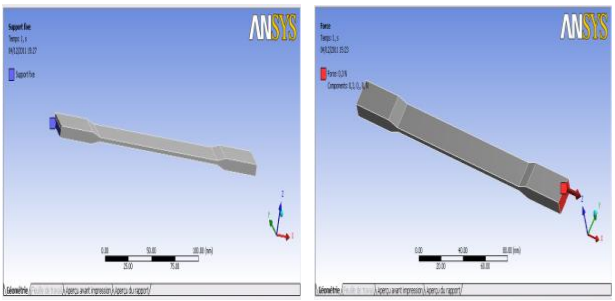


Figure 3: Applied Loads and boundary conditions

The stress distribution on the model of the test piece (figure 4) shows that the stress concentration area is located at the effective area of the specimen which presented the distribution of damage in the useful section.

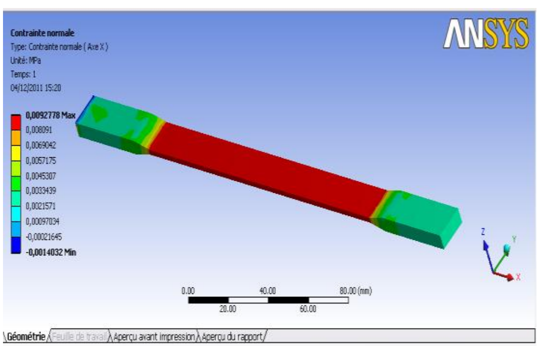


Figure.4: Distribution of the stresses in the test specimen during loading.

7. Results obtained by simulation (constant amplitude loading)

The tests are carried out for loading four bearings (30, 45, 65 and 85% of the load at break), if the load is of constant amplitude as our case, this represents the number of cycles until failure of the piece due to fatigue. First loading level to 30% of the breaking load:

($\sigma_a = 135\ MPa$):

$\sigma_a = [(\sigma_{max} - \sigma_{min})/2] = 135\ MPa$

$R = [\sigma_{min}/\sigma_{max}] = 0.1$

$\sigma_{max} = 300\ MPa$ and $\sigma_{min} = 30\ MPa$

Section of the test is (15*2.2) mm^2,

$f_{max} = 9\ 900\ N$ et $f_{min} = 990\ N$

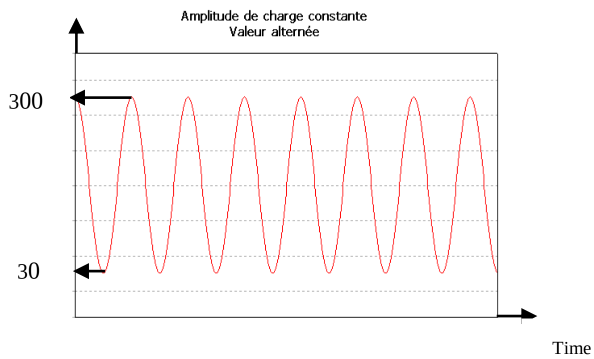


Figure.5: The number of cycles obtained in the 1 step

The number of cycles obtained in the first loading stage (30% of the load at break) is 1 655 050 cycles.

8. Comparison between the experimental values and the values obtained by the MEF simulation (ANSYS)

The results of stress tests in experimental life and obtained by simulation for quads bearing loads with a load ratio R = 0.1 are shown in table 3.

Table 3
Comparison between experimental values and obtained values by simulation MEF (ANSYS).

Ampli. (%UTS)	Specimen (1)	Specimen (2)	Specimen (3)	Specimen (4)	Specimen (5)	medium	simulation	gap (%)
30	10^6+X	10^6+X	10^6+X	10^6+X	10^6+X	10^6	165 5050	65,50
45	208 131	366 876	796 416	792 227	122 000	45 7130	385 752	15,61
65	20 278	15 325	19 224	28 190	28 146	22 233	19884	10,56
85	3516	927	765	451	1331	1398	867	37,98

9. Interpretation of the results obtained

In this table is shown a comparison between the experimental values and those obtained by the FEM simulation (ANSYS) It is noted that: the values of cycle numbers obtained by the finite element method are less than but close to the average values obtained by experimental tests, so the simulation results are acceptable because the relative error of prediction of total lifetime compared to averages of experimental results is less than 20% for both loads 45% and 65%.

In the first case of loading 30% UTS: experimentally lifespan is not achieved because the test conditions specified that the testing stopping criterion is the breaking of the specimen or duration life of 106 cycles, thus the value obtained by the simulation N = 1 655 050 cycles is a prediction of the life can be considered a good prediction.

For the latter case of loading 85% UTS, notice that the gap is 37.98 (exceeds 20%), due to high number of cycles for the sample 1 and 5, but for the other specimens tested values of life obtained are very close to the simulated value.

For the most loins experimental results with the results obtained by simulating the explanation is as followings:
The experimental tests are characterized by a dispersion of the values of the life which is mainly due to the heterogeneous nature of the composite material. In addition, the samples may not have comparable characteristics: volume fraction distribution of defects, tensile strength in static, etc.

10. Wöhler curves (simulation)

The operation of the fatigue testing is conventionally carried out by plotting the Wohler curve of the material. This curve shows the trend of the load level as a function of the life of the material. The figure.6 presents the Wöhler curve of the composite glass / epoxy obtained by the simulation. In figure 6, we observed only the results obtained from modeling compared with those obtained experimentally. These results show that when the load level is high, the failure criterion is reached for a few hundred cycles. By against, when the load is low the failure criterion is reached for a large number of cycles.

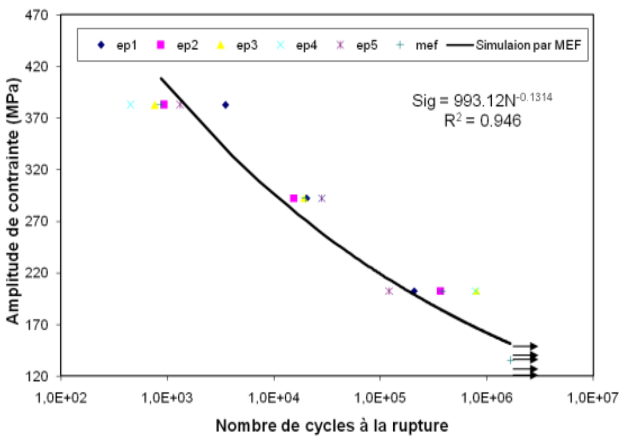


Figure 6: The Wöhler curve of composite glass / epoxy simulation.

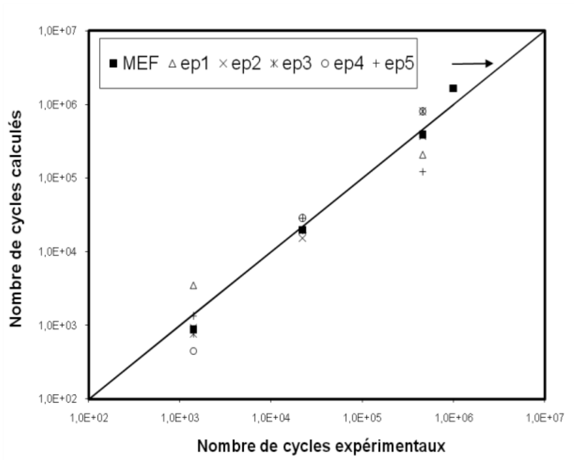


Figure.7: Comparison between the predictions of the experimental life and calculated by finite element method

Figure 7 shows the results of fatigue tests under stress to constantes.la prediction loads lifetime is given by the simulation in MEF and by the experimental tests. It may be noted also in the same figure that the results of numerical simulations correlate well with the experimental results.

11. Results obtained by simulation (Load variable amplitude block)

We did some testing Up-Down and Bottom-Up, This is tensile tests These tests are performed with both increasing and decreasing blocks, a number of cycles in the first constraint is imposed and the test level is continuous with another level of loading up to failure, stress levels are selected on the curve Wohler. Table 6 together the results of stress Low High and High-Low:

- 1st case croissants -Block see Figure 8 (a):

(Block 1: 0 = σ_{min} *MPa* and $\sigma_{max} = 45\%$ *MPa*)

(Block 2: 0 = σ_{min} *MPa* and $\sigma_{max} = 65\%$ *MPa*)

- 2nd block Diminishing see Figure 8 (b):

(Block 1: 0 = σ_{min} *MPa* and $\sigma_{max} = 65\%$ *MPa*)

(Block 2: 0 = σ_{min} *MPa* and $\sigma_{max} = 45\%$ *MPa*)

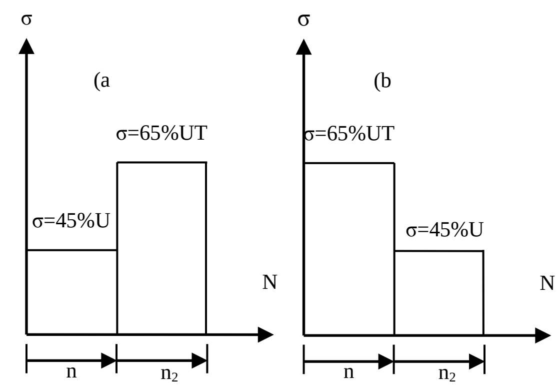


Figure 8: Representation of loads blocks for the first case.

Table 4: Comparison between the three loading levels for increasing and decreasing blocks

Croissants blocks		**Decreasing blocks**	
loading (MPA)	Number of total sycles	Chargement (*MPA*)	Number of total sycles
1st case		**1st case**	
Bloc1 :0-45%		Bloc1 :0-65%	
Bloc2 :0-65%		Bloc2 :0-45%	
	199 737		281 563
2nd case		**2nd case**	
Bloc1 :0-65%		Bloc1 :0-85%	
Bloc2 :0-85%		Bloc2 :0-65%	
	10 465		12 330
3rd case		**3rd case**	
Bloc1 :0-45%		Bloc1 :0-85%	
Bloc2 :0-85%		Bloc2 :0-45%	
	193 254		249 754

It is observed that for all the results obtained by modeling in loading block amplitude variables that the life of the growing blocks are less than that of decreasing blocks as shown in Table 4.

12. Conclusion

The cyclic fatigue tests were carried out by controlling the number of cycles given with a near zero load ratio that equals 0.1 and several loading levels (loading a constant amplitude). The analysis by the finite element method based on changes in the number of cycles it possible to monitor the different damage mechanisms during fatigue and identify those most critical resulting in material failure.

Analysis of the results obtained in tests by fatigue simulation showed that the results of these trials have also allowed drawing the Wöhler curve using the NR lifetime criterion (corresponds to the total breakdown of the test piece). This curve shows a dispersion of the service life in the case of experimental tests this is mainly due to the heterogeneous nature of the material composite.ces results have shown that when the loading level is close to that of the static rupture, a complete departure from the first cycle is recognized. By against, at low loading levels breakage is not even reached beyond 10^6 cycles.

For loads in variable amplitude block is observed that for all the results obtained by modeling in loading block amplitude variables that the life of the growing blocks are less than that of decreasing blocks.

References

[1] Barlas Bruno, Etude du comportement et de l'endommagement en fatigue d'alliages d'aluminium de fonderie, Doctorat Sciences Génie des Matériaux, ENSMP - Centre des Matériaux P.M. Fourt, ENSMP, PARIS p.224, 2004.

[2] D. Baptiste, S.J. Wang et D. François, "Comportement en fatigue d'un unidirectionnel en verre/époxy", AMAC 1990

[3] C.A.H Sawadogo,Comportement en fatigue des composites monolithiques et sandwiches: detection et suivi de l'endomagement par techniques non destructives, Thèse de doctorat de l'université de Lille 1,2009

[4] Nechnech W., 2000."Contribution à l'étude numérique du comportement du béton et des structures en béton armé soumises à des sollicitations thermiques et mécaniques couplées. Une approche thermo-élasto-plastique endommageable." Thèse de Doctorat, INSA de Lyon, France.

[5] Fatmi L., 1994. "Modélisation de l'endommagement des matériaux hétérogènes par réanalyse après modification locale de la matrice de rigidité." Thèse de doctorat, Université du Maine, Le Mans, France.

[6] Jirásek M., 1999. "Numerical modeling of deformation and failure of materials." Short Course, Aachen, pp. 3-7.

[7] Rashid M.M., 1998. "The arbitrary local mesh replacement method : an alternative to remeshing for crack propagation analysis." Computer Meth. in Appl. Mech. And Engng., vol.154, pp. 133-150.

[8] Bouchard P.O., Bay F., Chastel Y., 2000. "Modelling of discrete crack propagation." Congrès Computational techniques for materials, composites and composite structures, Leuven, pp. 217-223.

[9] Hillerborg A., Modeer M., Petersson P.E., 1976. "Analysis of crack formation and crack growth in concrete by means of fracture mechanics and finite elements." Cement and Concrete Research, vol.6, pp. 773-782.

[10] Diouf B., 2005. "Analyse statistique de l'évolution de l'endommagement dans des matériaux hétérogènes." Thèse de doctorat, Université du Maine, Le Mans,France.

[11] Bouchard P.O., Bay F., Chastel Y., Tovena I., 2000. "Crack propagation modelling using an advanced remeshing technique." Computer methods in applied mechanics and engineering, vol. 189(3), pp. 723-742.